REMOVAL OF ORGANIC MATTER IN BIOLOGICAL TREATED PALM OIL MILL EFFLUENT (POME) BY USING COMBINATION OF COAGULANTS

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CERTIFICATION OF APPROVAL

Removal of Organic Matter in Biological Treated Palm Oil Mill Effluent (POME) by Using Combination of Coagulants

By

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Approved by.

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Tronoh, Perak

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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MOHD KHAIRULARIFIN BIN HASSAN

ABSTRACT

Palm oil production is one of the contributors of Malaysia's economy. The palm oil mill effluent (POME) is highly polluted wastewater that pollutes the water body and environment if discharged untreated. The biologically treated POME is still coloured and have some concentration of non-biodegradable organics. In this project, the chemical coagulation is used to treat the biological treated POME by using combine coagulant. The method to achieve the objectives of this project is by using jar test. There are two stages of jar test, which the first stage is to determine the optimum pH and the second stage is to determine the optimum dosage of combine coagulant, while verifies the best combined coagulant. As the result from the jar test, alum and ferric chloride is the most effective combine coagulant. While, the quality of the effluent is enhanced with the percentage removal of total suspended solid is 13.3%, colour removal is 95.8% and turbidity removal is about 95.9%. However for COD, further treatment is needed.

ACKNOWLEDGEMENT

I would like to take this opportunity to acknowledge and thank everyone that has given me all the supports and guidance throughout the whole period of completing the final year project. Firstly, many thanks to the university and the Final Year Project coordinators that have coordinated and made the necessary arrangements.

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INTRODUCTION

1.1 Background of Study

Oil Palm (*Elaeis guineensis*) is one of the most adaptable crops in tropical world has expanded significantly over recent years. As the demand for vegetable oils increases, the oil palm is likely to become an increasingly important crop. Malaysia currently accounts for 51 % of world palm oil production and 62% of world exports, and also for 8% and 22% of the worlds' totals production and exports of oils and fats [1]. As the biggest producer and exporter of palm oil and palm oil products, Malaysia has an important role to play in fulfilling the growing global need for oils and fats in general.

Besides the main products, crude palm oil (CPO), the mills also generate many by-products and liquid wastes, which may have a significant impact on the environment if they are not dealt with properly. On an average a standard palm oil mill, for each tone of fresh fruit bunch (FFB) processed, generates about 1 tonne of liquid waste with biochemical oxygen demand (BOD) 37.5 kg/L, chemical oxygen demand (COD) 75 kg/L, suspended solids (SS) 27 kg/L and oil and grease 8 kg.[2]

In Malaysia, the ponding system is the most commonly used. This system consists of series of anaerobic and facultative ponds to degrade POME until it meets the standard requirement of Malaysian Department of Environment (DOE) under the Environmental Quality Act (1974).

1.2 Problem Statement

Palm oil industries are confronting enormous challenges to meet the increasingly severe environmental regulations. Due to the production of large volume of POME, it must be treated to an acceptable level before it is discharged to the environment or it will cause serious and undesirable problems.

The oil from POME can be hazardous to the stream by poisoning marine and freshwater life, interfering with gas exchanges necessary for life such as oxygen gas. An accumulation of oil can cause conditions to become anaerobic and it has found that 0.1 ppm of oil in water can disturb the biological cycle in the streams. [3]

However, the practice of anaerobic treatment only is normally incapable of complying with the standard requirements set by the regulator [4]. The discharge is still coloured and contains high concentration of non-biodegradable organics which require further treatment.

1.3 Objectives

The objectives of this project are as follow:

1. To determine the characteristics on biological treated POME by laboratory experiment;
2. To study on the feasibility of chemical treatment by using combined mixture coagulant in degradation of treated POME;
3. To determine the optimum dosage of the best combined mixture coagulant in treating the effluent; and
4. To improve the quality of effluent.

1.4 Scope of work

The scope of work of this research is to analyze the efficiency of combine coagulant in treating the treated POME from anaerobic pond system in FELCRA Nasaruddin. In analyzing the data, several testing from jar test is conducted such as:

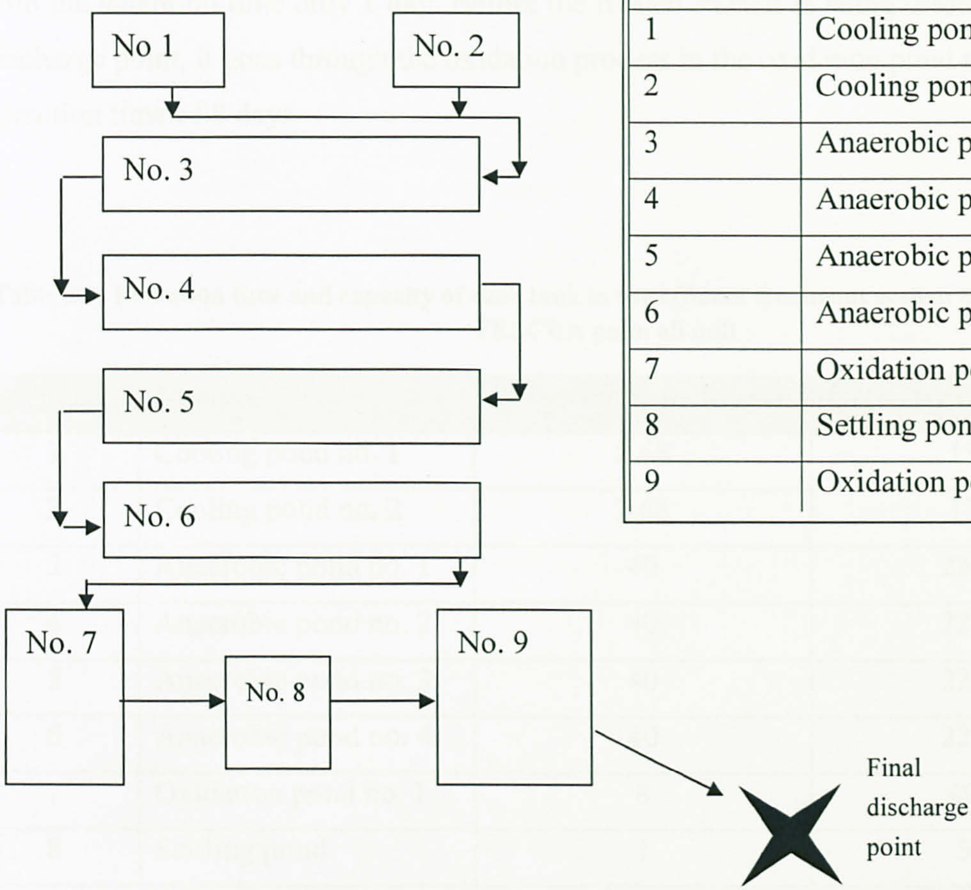
1. Chemical Oxygen Demand (COD)
2. Total Suspended Solid (TSS)
3. Colour
4. Turbidity

CHAPTER 2

LITERATURE REVIEW

2.1 Palm Oil Mill Effeluent

The effluent treatment system of Nasaruddin FELCRA palm oil mill used ponding system. The stages of treatment are shown in figure 2.1 below.



No. pond	Name of pond
1	Cooling pond no. 1
2	Cooling pond no. 2
3	Anaerobic pond no. 1
4	Anaerobic pond no. 2
5	Anaerobic pond no. 3
6	Anaerobic pond no. 4
7	Oxidation pond no. 1
8	Settling pond
9	Oxidation pond no. 2

Figure 2.1: The effeluent treatment system of Nasaruddin FELCRA palm oil mill

As POME being discharge into the system, it will go through cooling process. This is because the fresh raw POME from the mill is hot and the temperature is 45°C. The detention time for each cooling pond is 2.86 days with the capacity of 1355 m^3.

After the cooling process, it will go through the anaerobic process with the detention time for 40 days in the anaerobic pond no. 1. In this pond, the sludge (anaerobic microorganism) will degrade the POME under anaerobic condition. It continues to the anaerobic pond no 2, anaerobic pond no. 3 and anaerobic pond no. 4 which is the detention time for each pond is 40 days. The volume of each anaerobic pond is 22000 m^3.

The next process is oxidation process. in this pond, the treated POME from anaerobic pond is being aerated in order to remove the unwanted gases, such as methane. The detention time is 8 days. After that, the treated POME is discharge to settling pond with the detention time only 1 day. Before the treated POME is being discharge to final discharge point, it goes through the oxidation process in the oxidation pond no 2 with the detention time of 8 days.

Table 2.1: Detention time and capacity of each tank in the effluent treatment system of Nasaruddin FELCRA palm oil mill

No. pond	Name of pond	Detention time (days)	Capacity (m^3)
1	Cooling pond no. 1	2.68	1355
2	Cooling pond no. 2	2.68	1355
3	Anaerobic pond no. 1	40	22000
4	Anaerobic pond no. 2	40	22000
5	Anaerobic pond no. 3	40	22000
6	Anaerobic pond no. 4	40	22000
7	Oxidation pond no. 1	8	4000
8	Settling pond	1	500
9	Oxidation pond no. 2	8	4000

Anaerobic ponds have the longest retention time in ponding system which is around 20–200 days [5]. Investigations by Yacob et al. (2006) showed that anaerobic pond had a higher emission of methane with an average methane composition of 54.4%

compared to open digester tank [6]. In addition to that, the methane composition from anaerobic ponds was also found to be more consistent in the gaseous mixture.

Methane emission in anaerobic ponds is influenced by mill activities and seasonal cropping of oil palm [6]. Open digesting tanks are used for POME treatment when limited land area is available for ponding system. Yacob et al. (2005) investigated on the methane emission from open digesting tanks where each tanks was half the capacity of anaerobic ponds (3600 m3) with retention time of 20 days [7]

Emission of methane gas from open digesting tank was found to be less than anaerobic pond with an average methane composition of 36.0%. Lower methane composition is due to the transfer of oxygen into the tank when feed is induced into the tank. Mixing in digesting tanks improves the digestion process as bacteria consortia are brought into more contact with food [8]. Nevertheless, mixing in open digesting tank only depends on slow bubbling and eruption of biogas which causes low conversion of methane gas.

2.2 Chemical Coagulation

Coagulation is the addition and rapid mixing of a coagulant, the resulting destabilizing of the colloidal and fine suspended solids, and the initial aggregation of the destabilized particles. Coagulant is the chemical that added into the wastewater to destabilize the colloid particles. From this, it result the floc formation from sequencing flocculation process.

2.2.1 Theory and concept of coagulation

The particles in wastewater be classified as suspended and colloidal, which is the size of suspended particles are larger than 1.0 μm and can be removed by gravity sedimentation. Because colloidal particles cannot be removed by sedimentation in a reasonable period of time, chemical method such as coagulants and flocculants aids must be used to help bring about the removal of these particles [9].

Aluminum and iron salt are commonly practiced in wastewater treatment. They are effective in removing the wide range of impurities from water, including colloidal particles and as well dissolve organic substances [10]. The higher the valance of the counter-ion, the more its destabilizing effect and lesser dose needed for coagulation [11].

The principal factors affecting the coagulations and flocculation of water or wastewater are turbidity, suspended solids, temperature, pH, cationic and anionic compositions and concentration duration and degree of agitation during coagulation and flocculation, dosage and nature of the coagulant.

The formation of the hydrolytic products formed from metal salt coagulants occurred in a very short time and they are readily absorbed onto the colloid particles and then cause destabilization of their electrical charge. The pH of the wastewater is essential for the enhancement of hydrolytic reaction.

While for dilute colloidal suspensions, the rate of coagulation may be extremely slow because of the low particulate concentrations, which cause an inadequate number of particulate contacts. The restablizations of the colloids occur from the relatively large coagulant dosages. The negatively charged colloids become positively charged due to existing positively charged reactive sites on the colloidal surfaces. [12]

2.2.2 *Aluminium sulphate (Alum)*

In the process of coagulation, aluminum sulphate or well known as alum is the most common coagulant used as coagulant. When alum is dissolved in water, it dissociates according to the following equation [13] :

$$Al_2(SO_4)_3 \rightarrow 2Al^{3+} + 3SO_4^{\;2-} \tag{2.1}$$

Because the water molecule is polar, it attracts Al^{3+} forming a complex ion according to the following:

$$Al^{3+} + 6H_2O \rightarrow Al(H_2O)_6^{3+} \tag{2.2}$$

In the complex ion , Al is called the *central atom* and the molecules of H2O are called *ligands*. The subscript 6 is the coordination number, the number of ligands attached to the central atom; the superscript 3+ is the charge of the complex ion. The whole assembly of the complex forms what is called a coordination sphere.

As indicated in Equation (2.1), aluminum has a coordination number of 6 with the water molecule. This means that no more water molecules can bind with the central atom but that any interaction would not be a mere insertion into the coordination sphere. In fact, further reaction with the water molecule involves hydrolysis of the water molecule and exchanging of the resulting OH□ ion with the H_2O ligand inside the coordination sphere. This type of reaction is called ligand exchange reaction.

2.2.3 *Ferric Chloride*

The ferric salts used as coagulant in water and wastewater treatment are $FeCl_3$ and $Fe_2(SO_4)_3$. They have essentially the same chemical reactions in that both form the $Fe(OH)_{3(s)}$ solid. When these coagulants are dissolved in water, they dissociate according to the following equations[14]:

$$FeCl_3 \rightarrow Fe^{3+} + 3Cl^- \tag{2.3}$$

The optimum pH range for ferric chloride is the same as ferric sulphate, which is from 4 to 12. The floc formed is generally a dense, rapid-settling floc. Ferric chloride is available in dry or liquid from.

2.2.4 *Ferrous Sulphate*

The ferrous salt used as coagulant in water and wastewater treatment is copperas, FeSO4 •7H2O. For brevity, this will simply be written without the water of hydration as FeSO4. When copperas dissolves in water, it dissociates according to the following equation[14]:

$$FeSO_4 \rightarrow Fe^{2+} + SO_4^{2-} \tag{2.4}$$

The complexes are $FeOH^{+}$ and $Fe(OH)_3^{-}$. Also note that the OH^{-} ion is a participant in these reactions. This means that the concentrations of each of these complex ions are determined by the pH of the solution. In the application of the above equations in an actual coagulation treatment of water, conditions must be adjusted to allow maximum precipitation of the solid represented by $Fe(OH)_{2(s)}$. To allow for this maximum precipitation, the concentrations of the complex ions must be held to the minimum. The values of the equilibrium constants given above are at 25°C.[14]

CHAPTER 3
METHODOLOGY

3.1 Materials and Equipment

The treated POME is collected from a discharged point of the anaerobic pond system at Nasaruddin FELCRA palm oil mill in Seri Iskandar. It was preserved at a temperature less than $4^{o}C$, before use.

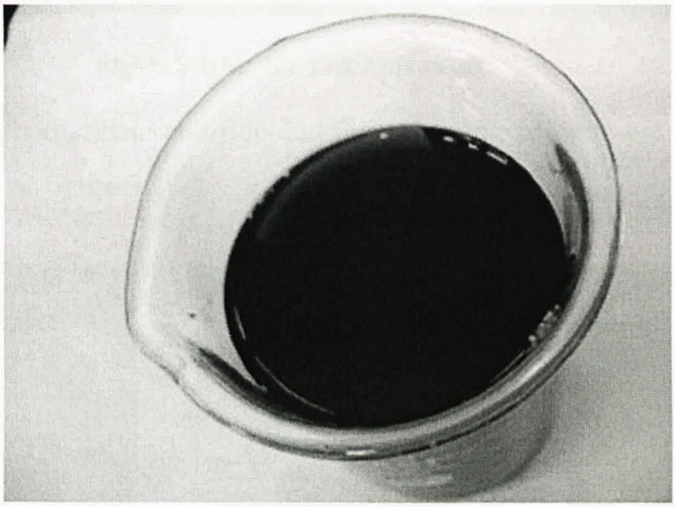
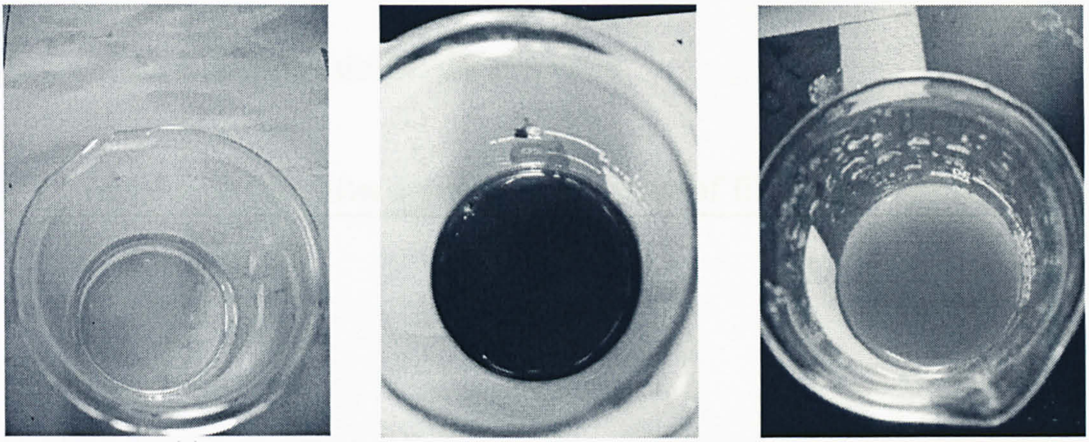


Figure 3.1(a): Biologically treated POME

A jar test apparatus were used in this study. The instruments used were shown in figure 3.1(b).

Figure 3.1(b): Jar Test Apparatus

Aluminum sulphate, ferric chloride and ferrous sulphate were used for this study as coagulant as shown in figure 3.1(c)



(a) (b) (c)

Figure 3.1(c): The coagulant (a) Aluminum sulphate (b) Ferric chloride (c) Ferrous sulphate

3.2 Analytical Method

3.2.1 COD test

For COD test, 3ml of each sample is measured and poured into each test tube containing potassium dichromate. After the tube is shaken properly on rotator, the tube is placed in the digester and set at 150°C. It is left for 2 hours. After 2 hours, the readings for each sample are taken down and the average of those reading is calculated.

3.2.2 Total Suspended Solid test

47mm filter disc is placed in the filter holder with the wrinkled surface upward by using tweezer to avoid addition moisture from fingers that will cause a weighing error. After that, 50ml of sample is filtered by applying vacuum to the flask. Slowly the vacuum is released from the filtering system and the filter disc is removed from the holder.

The disc is placed on a aluminum dish. The aluminum dish and filter are placed in a drying oven at 103°C for 1 hour. After 1 hour, the watch glass and filter are removed from the oven, and placed in a dessicator carefully about 15 minutes. It is allowed to cool to room temperature. The disc is removed the dessicator and weighted using an analytical balance.

Below is the formula to calculate the TSS value

$$TSS = \frac{\text{(residue on filter after drying, g) - (tare mass of filter after drying,g)}}{\text{sample size, L}}$$

3.2.3 Colour

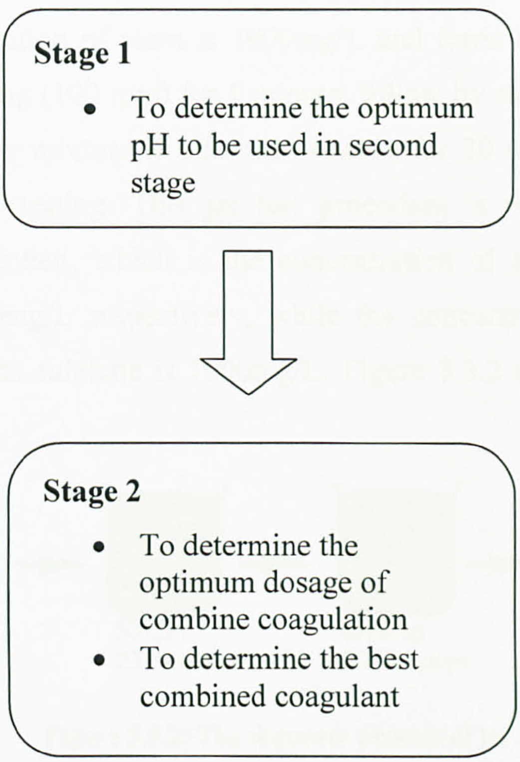
The sample is prepared by diluting with the dilution factor 1:10 and filled into the sample cells. After that, the sample is placed into the cell holder and scanned with DR 5000 Spectrophotometer. When the result is displayed, then it is multiplied with the dilution factor.

3.2.4 Turbidity

The sample is poured into the bottles specifically designed to be put into turbiditimeter. The reading is recorded down.

3.3 Experimental Procedure

The jar test is commonly used to determine the proper coagulant and the chemical dosages required for the coagulation of wastewater. In this project, there are two stages in order to treat the biologically treated POME as shown in the flow diagram below



3.3.1 First stage

The volume of the each beaker is 1 litre. The sample is adjusted according to the values of pH which are from 2 to 12. Since the pH of raw sample is 8.86, the pH 2 until

8 is adjusted by adding sulfuric acid, H_2SO_4. While, for pH 10 and pH 12 is adjusted by adding sodium hydroxide NaOH.

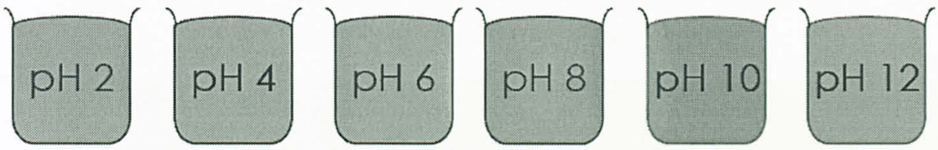


Figure 3.3.1: Sample is adjusted from pH 2 to pH 12

After that, the combine coagulation, alum and ferric chloride are added in each beaker. The concentration of alum is 1000mg/L and ferric chloride is 1000mg/L. The mixture is rapid mixing (100 rpm) for 1 minute; follow by slow mixing of 30 rpm about 20 minutes. Then, the mixture is allowed to settle for 30 minutes. The supernatant is collected for further testing. This jar test procedure is repeated with the different combination of coagulant, which is the concentration of alum and ferrous sulphate, 1000mg/L and 1000mg/L respectively, while the concentration of ferric chloride is 1000mg/L and ferrous sulphate is 1000mg/L. Figure 3.3.2 indicates the process of jar test.

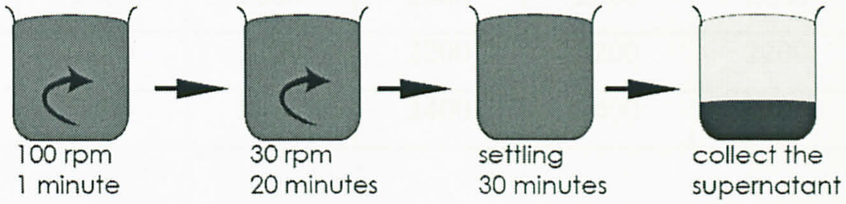


Figure 3.3.2: The sequence process of jar test

After the supernatant is tested for COD, TSS, colour and turbidity, the graph is plotted and the optimum pH is determined from the graph.

3.3.2 Second stage

In this stage, the jar test is to determine the optimum dosage of combine coagulant using the optimum pH from the first stage. It also to obtain the best combine coagulant in treating biologically treated POME. The volume of sample is 500mL. Each beaker is added combined coagulant with varied dosage as stated in table 3.3.2(a) and 3.3.2 (b) for the volume for each coagulant to be added.

Table 3.3:1 Dosage for each combine coagulant

Beaker	Dosage concentration (mg/L)					
	Combine coagulant A		Combine coagulant B		Combine coagulant C	
	Alum	$FeCl_3$	Alum	$FeSO_4$	$FeCl_3$	$FeSO_4$
1	200	200	200	200	200	200
2	400	400	400	400	400	400
3	600	600	600	600	600	600
4	800	800	800	800	800	800
5	1000	1000	1000	1000	1000	1000
6	1200	1200	1200	1200	1200	1200
7	1400	1400	1400	1400	1400	1400
8	1600	1600	1600	1600	1600	1600
9	1800	1800	1800	1800	1800	1800
10	2000	2000	2000	2000	2000	2000
11	2200	2200	2200	2200	2200	2200
12	2400	2400	2400	2400	2400	2400

Table 3.3:2 Volumes for each combine coagulant

Beaker	Volume (mL)					
	Combine coagulant A		Combine coagulant B		Combine coagulant C	
	Alum	$FeCl_3$	Alum	$FeSO_4$	$FeCl_3$	$FeSO_4$
1	0.167	0.167	0.167	0.5	0.167	0.5
2	0.33	0.33	0.33	1	0.33	1
3	0.5	0.5	0.5	1.5	0.5	1.5
4	0.67	0.67	0.67	2	0.67	2
5	0.83	0.83	0.83	2.5	0.83	2.5
6	1	1	1	3	1	3
7	1.16	1.16	1.16	3.5	1.16	3.5
8	1.33	1.33	1.33	4	1.33	4
9	1.5	1.5	1.5	4.5	1.5	4.5
10	1.67	1.67	1.67	5	1.67	5
11	1.83	1.83	1.83	5.5	1.83	5.5
12	2	2	2	6	2	6

The calculation of each dosage can be referred to appendix 2-I and 2-II. The procedure for this jar test is the same with the first stage. In figure 3.3.3, 3.3.4 and 3.3.5 show the series of supernatant of each jar test using each combine coagulant.

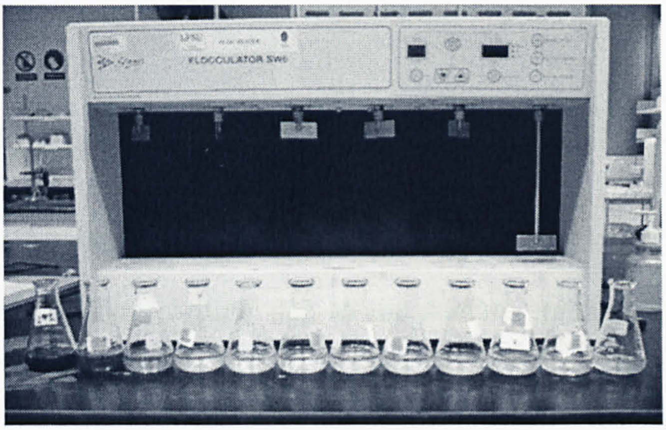


Figure 3.3.3 A series of supernatant of jar test using combination coagulant alum and ferric chloride

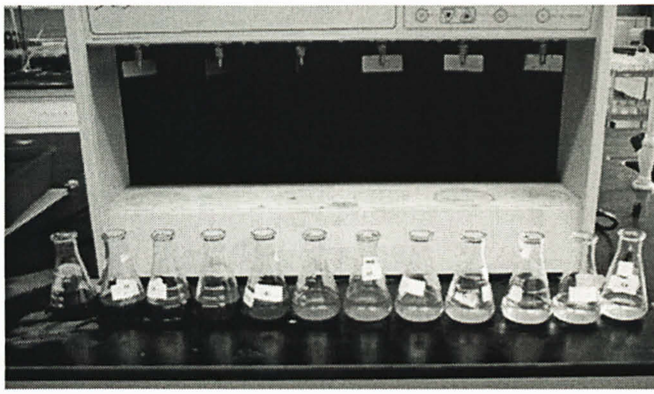


Figure 3.3.4 A series of supernatant of jar test using combination coagulant alum and ferrous sulphate

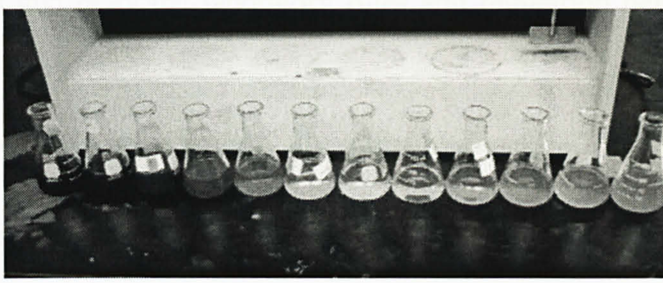


Figure 3.3.5 A series of supernatant of jar test using combination coagulant ferric chloride and ferrous sulphate

3.4 Hazard Analysis

In the time for completing the project, there might be unnecessary incident due to unsafe condition and lack of Health, Safety and Environment (HSE) awareness. Several hazardous incidents might happen while conducting this project as stated in hazard identification.

3.4.1 Hazard identification

3.4.1.1 The POME sample spill out from the container

When it happen, a slippery floor due to the sample spillage and might bring hazard to the person in the laboratory.

3.4.1.2 The broken laboratory apparatus

Since some of the apparatus in the lab are made from glass, there might be an incident when the apparatus is handled in the unsafe condition and breaks. The broken can injure people around it if they are not aware of the hazard.

3.4.2 Hazard Prevention

There is several ways to avoid people from being exposed to the hazard.

- Understand and obey the laboratory rules and regulation before conducting the experiment
- Using laboratory coat to prevent any spillage of sample
- Wearing shoes while performing the experiment
- To make sure the place is tidy and clean before and after conducting the experiment

CHAPTER 4

RESULT AND DISCUSSION

4.1 Characteristics of biological treated POME

The characteristic of treated POME from anaerobic pond system at Nasaruddin FELCRA is shown in table below. The parameter is tested in Environmental Laboratory, Civil Department.

Table 4.1:1 Characteristic of biological treated POME

Parameter	Value
COD	880 mg/L
TSS	80 mg/L
Turbidity	135.3 NTU
Colour	5500 PtCo
pH	8.86

From the raw sample of treated POME before undergoing chemical treatment is contained moderate COD which is 880 mg/L with total suspended solid is 80 mg/L. While, the turbidity is 135.3 NTU and colour is 5500 PtCo. The pH is 8.86, which is alkaline.

4.2 Optimum pH

In the first stage of jar test, the supernatant from all beaker which are the pH is being adjusted from 2 to 12 were tested. The test involves COD, TSS, colour and turbidity and the reading is plotted to each graph as shown in figure 4.2(a), 4.2(b), 4.2(c) and 4.2 (d).

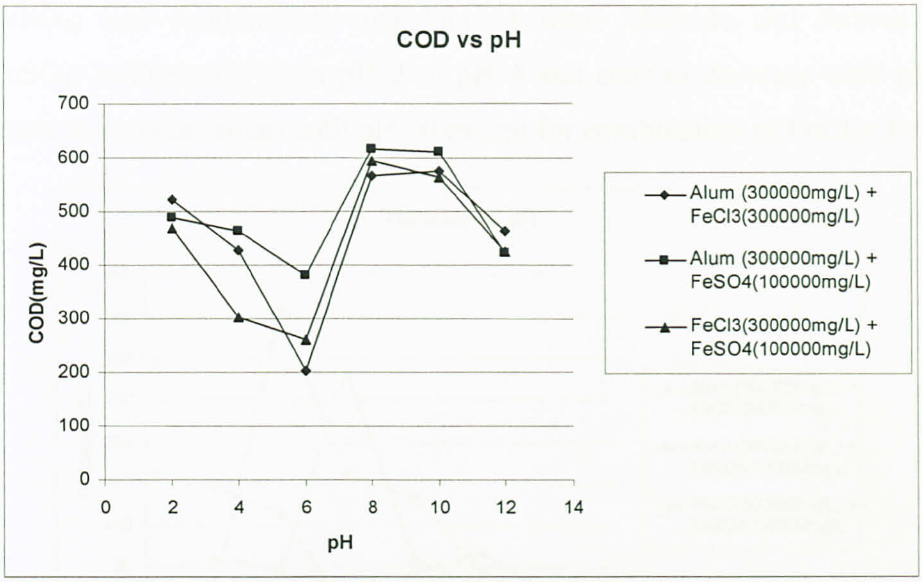


Figure 4.2(a): Graph of COD versus pH for each combine coagulant

From the graph 4.2(a), the reading of COD is decreased with the increment the value of pH. While at value of pH 6, the there is an increment in COD reading due to the reversal of particles charges and then to destabilize them. Until pH 8 and 10 the COD reading is constant and decrease again at the value pH 12.

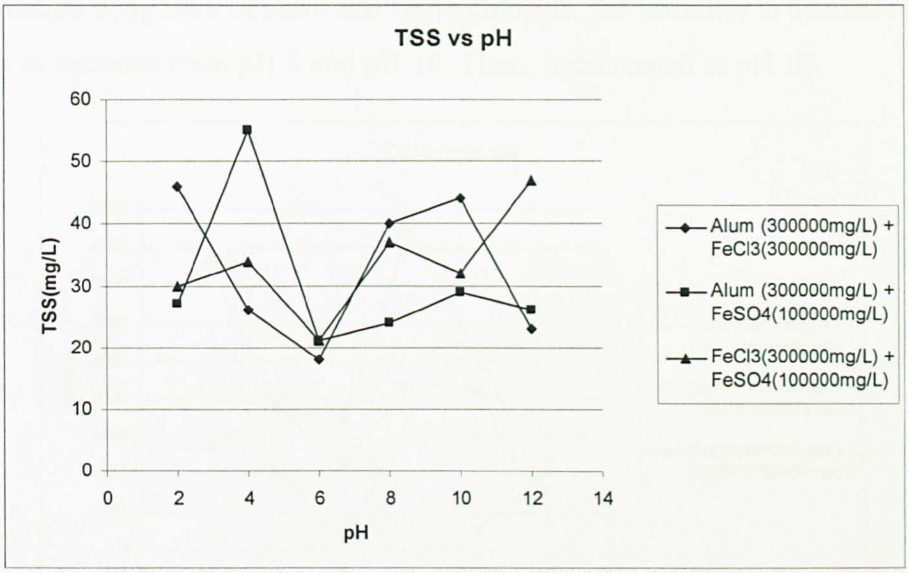


Figure 4.2(b): Graph of TSS versus pH for each combine coagulant

From the graph 4.2(b), the reading of TSS is decreased with the increment the value of pH. However, for the combination coagulant alum and ferrous sulphate

(Alum+$FeSO_4$) and combination coagulant of ferric chloride and ferrous sulphate ($FeCl_3$+$FeSO_4$) is increased from pH 2 to pH 4 and start to decrease until pH 6. The reading starts to increase again until pH 10 except for combination of $FeCl_3$+ $FeSO_4$.

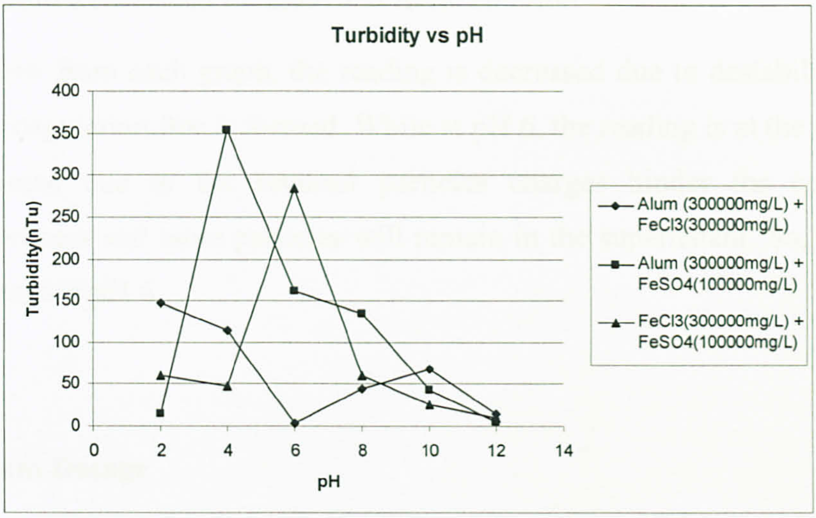


Figure 4.2(c): Graph of turbidity versus pH for each combine coagulant

The graph 4.2(c) shows for combination coagulant of alum and ferrous sulphate and combination coagulant of ferric chloride and ferrous sulphate, the turbidity is increased until pH 4 and pH 6 respectively, and decreased until pH 12. Different from the combination coagulant of alum and ferric chloride, the turbidity is decreased until pH 6 and start to increase from pH 6 and pH 10. Then, it decreased at pH 12.

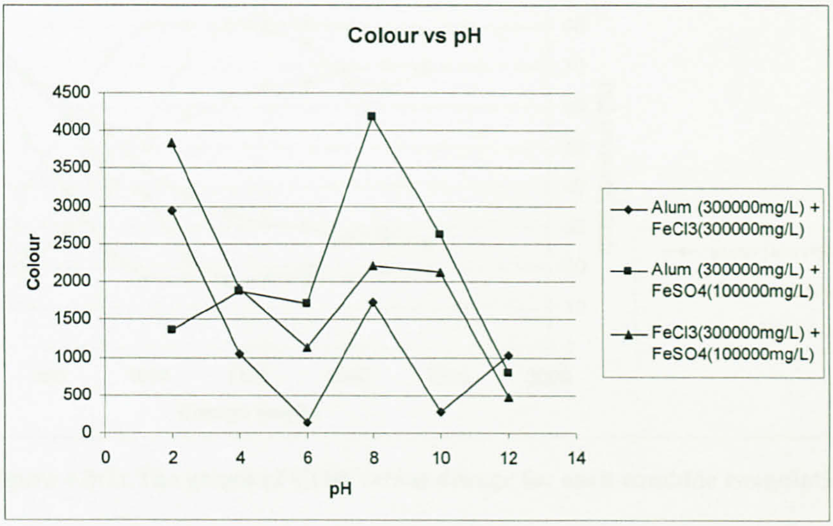


Figure 4.2(d): Graph of colour versus pH for each combine coagulant

From the graph 4.2(d), the combine coagulant of alum and ferric chloride and ferric chloride with ferrous sulphate show the colour is decreased respectively with pH until pH 6. Then, the reading is start to increase until pH 8 and decrease until pH 12 except for combine coagulant of alum and ferric chloride.

As show from each graph, the reading is decreased due to destabilization of the colloids and coagulation floc is formed. While at pH 6, the reading is at the optimum and start to increase due to the reversal particles charges hinder the completion of coagulation process and more particles will remain in the supernatant. So, the optimum pH for first stage is pH 6.

4.3 Optimum Dosage

4.3.1 COD test

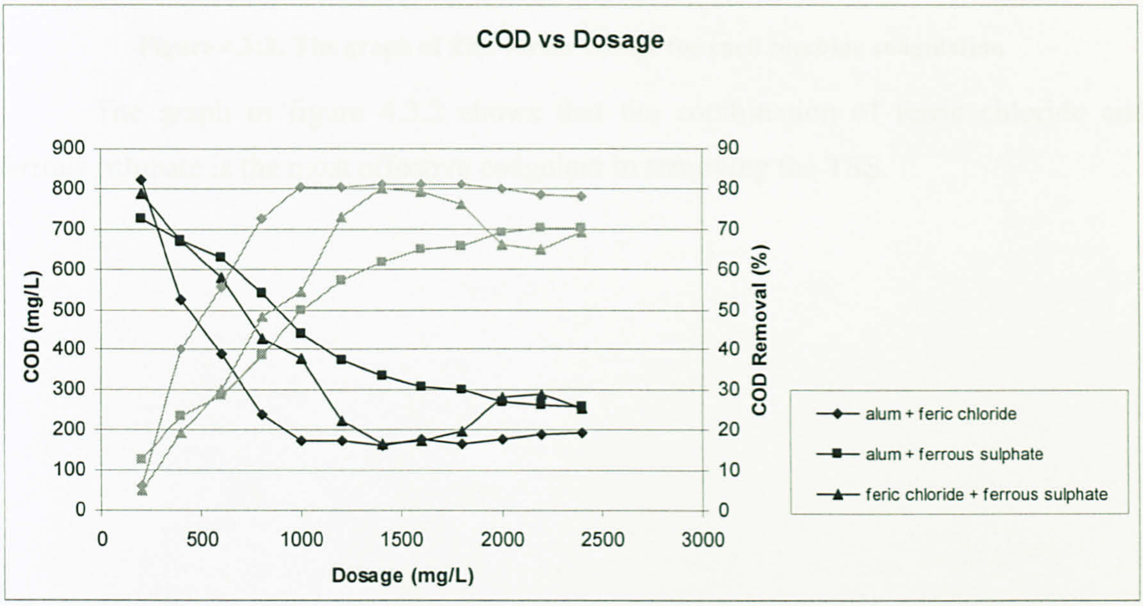


Figure 4.3:1: The graph of COD versus dosage for each combine coagulation

The graph in figure 4.3.1 shows the reading of COD is decreased as the amount of dosage for each combine coagulant is increased. While the percentage COD removal is increased. As we can see, the combination of alum and ferric chloride is the most effective coagulant in removing the COD at dosage of 1000mg/L of alum and 1000mg/L of ferric chloride. The percentage removal is 80%.

4.3.2 TSS test results

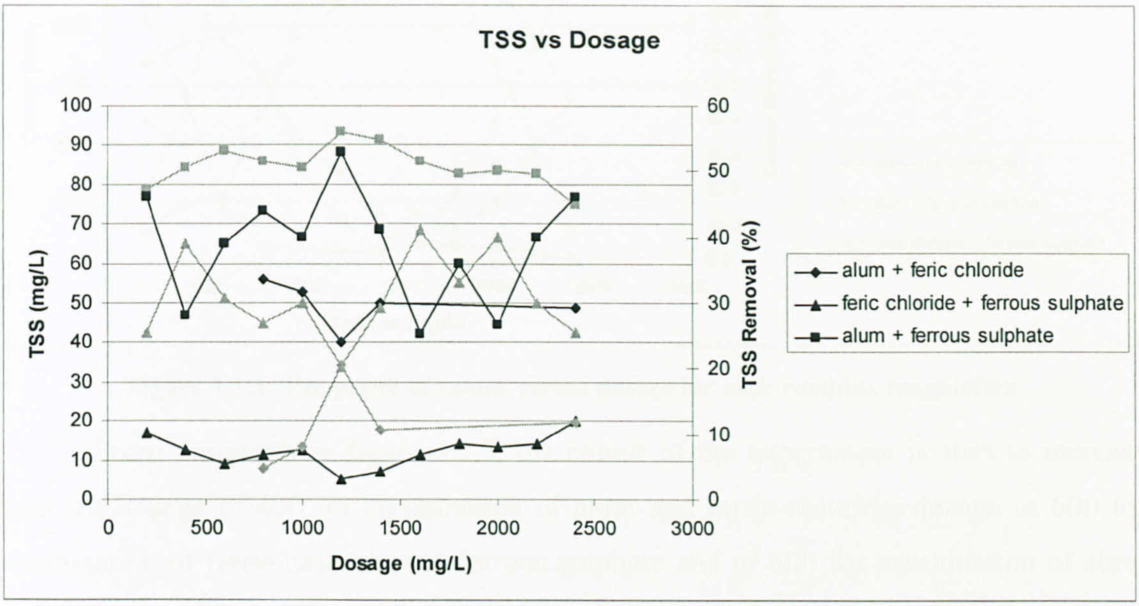


Figure 4.3:2: The graph of TSS versus dosage for each combine coagulation

The graph in figure 4.3.2 shows that the combination of ferric chloride and ferrous sulphate is the most effective coagulant in removing the TSS.

4.3.3 Colour test results

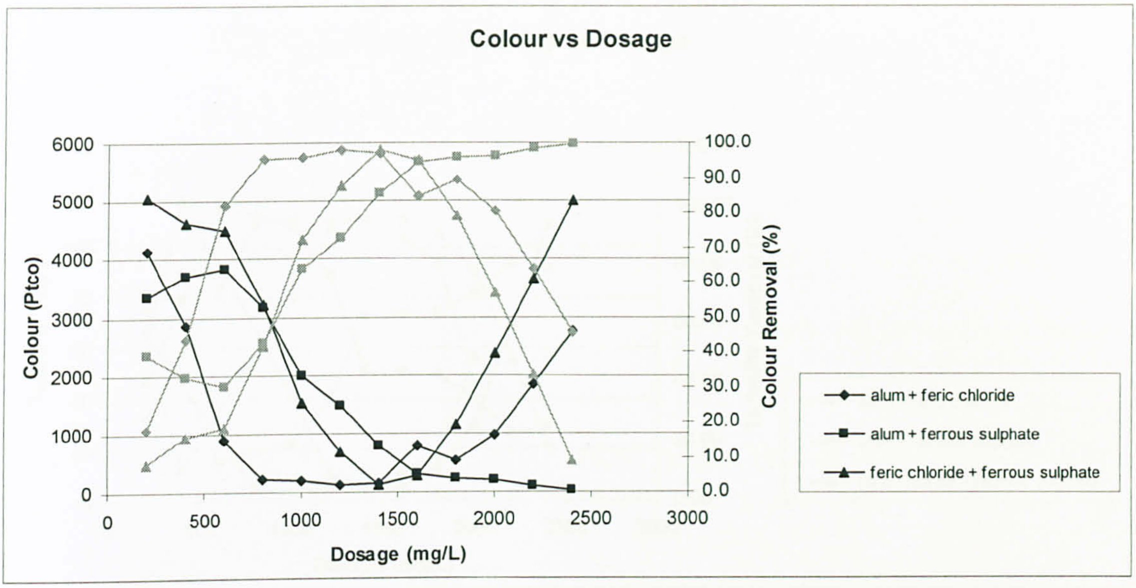


Figure 4.3:3: The graph of colour versus dosage for each combine coagulation

From the graph in figure 4.3.3, the colour of the supernatant is start to increase until the dosage of 400 for combination of alum and ferric chloride, dosage of 600 for combination of ferric chloride and ferrous sulphate and of 800 for combination of alum and ferrous sulphate. Then, the reading is decrease until the dosage of 1400 and the colour of supernatant is increased again except for supernatant using combination coagulant of alum and ferrous sulphate.

4.3.4 Turbidity test results

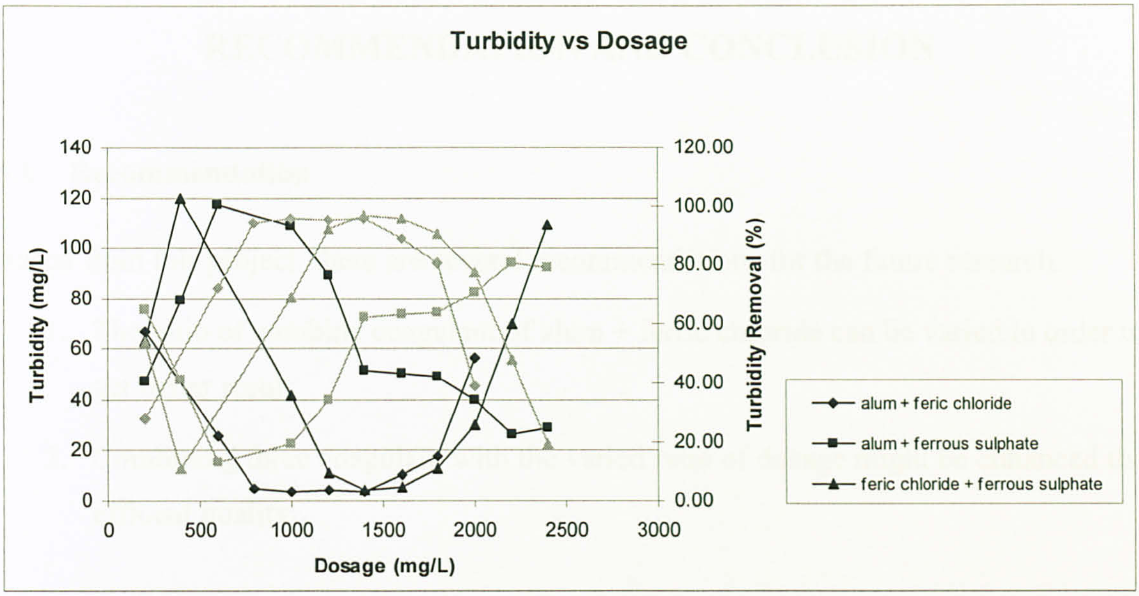


Figure 4.3:4: The graph of turbidity versus dosage for each combine coagulation

As shown in figure 4.3.4, shows the turbidity is decreased as the amount of dosage for each combine coagulant is increased except of supernatant using combination coagulant alum and ferrous sulphate, while it start to decrease at dosage of 600. The supernatant using combine coagulant alum and ferric chloride is decreased and the graph is in stable.

From this stage, the jar test show the most effective combination coagulant is alum and ferric chloride with the dosage of 1000mg/L of alum and 1000mg/L of ferric chloride with value of COD is 174 mg/L, TSS is 52.6 mg/L, turbidity at 3.8NTU and colour at 213.3 Ptco.

CHAPTER 5
RECOMMENDATION AND CONCLUSION

5.1 Recommendation

Based from this project, there are several recommendations for the future research.

1. The ratio of combine coagulant of alum + ferric chloride can be varied in order to get better result.
2. Combining three coagulant with the varied ratio of dosage might be enhanced the effluent quality.

5.2 Conclusion

From this project, the chemical treatment is the best choice in treating the biologically treated POME by alum + ferric chloride as the most effective combine coagulant. The optimum dosage for this combine coagulant is 1000mg/L for alum with 1000mg/L for ferric chloride with pH 6. While, the quality of the effluent is enhanced at the optimum dosage with the value of COD is 174 mg/L, TSS is 52.6 mg/L, turbidity at 3.8NTU and colour at 213.3 Ptco. The percentage removal of TSS is 13.3%, colour removal is 95.8% and turbidity removal is about 95.9%. However for COD, further treatment is needed.

REFERENCES

[1] Malaysia Palm Oil Production Council (MPOPC) homepage http://www.mpoc.org.my/main_ind_01.asp.

[2] G.D. Najafpour ,*, A.A.L. Zinatizadeh , A.R. Mohamed , M. Hasnain Isa , H. Nasrollahzadeh, High-rate anaerobic digestion of palm oil mill effluent inan upflow anaerobic sludge-fixed film bioreactor, process biochem. 41 (2005) 370-379

[3] Bassim H. Hameed, Abdul Latif Ahmad, Ng Ai Hoon. Removal of residual oil from palm oil mill effeluent using solvent extraction method. 38 (2003) 33-42

[4] Siew. O. B. 2006. Treatment of Palm Oil Mill Secondary Effeluent (POMSE) Using Fenton Oxidation System, M, Eng, Thesis, Universiti Teknologi Malaysia.

[5] Chan, K.S., Chooi, C.F. Ponding System for palm oil mill effluent treatment. In: Proceedings of the Regional Workshop on Palm Oil Mill Technology & Effluent Treatment, pp. (1984)185–192.

[6] Yacob, S., Hassan, M.A., Shirai, Y., Wakisaka, M., Subash, S., Baseline study of methane emission from anaerobic ponds of palm oil mill effluent treatment. Science of the Total Environment 366, (2006). 187–196.

[7] Yacob, S., Hassan, M.A., Shirai, Y., Wakisaka, M., Subash, S. Baseline study of methane emission from open digesting tanks of palm oil mill effluent treatment. Chemosphere 59, (2005) 1575–1581

[8] Leslie Grady Jr., C.P., Daigger, G.T., Lim, H.C., 1999. Biological Wastewater Treatment, second ed. CRC Press. Revised & Expanded.

[9] Metcalf & Eddy. Wastewater enginerring. 4^{th} Edition. New York; McGraw Hill; 2003, pg. 475-486

[10] Duan, J. M. and J. Gregory. 2003. Coagulation by Hydrolyzing Metal Salts. Advance in Colloid and Interface Science. 100-102:475-502

[11] Al-Malack, M. H.,N. S. Abuzaid, and A. H. El-Mubarak, 1999. Coagulation of Polymeric Wastewater Dsicharge by A Chemical Factory. Water Research Vol. 33 (2): 521-529

[12] Reynolds, Tom D. Unit Operations and Process in Environmental Engineering pg 15-30

[13] Sincero, A. P. (1968). Sludge production in coagulation treatment of water. Master's thesis, Asian Institute of Technology, Bangkok, Thailand, 12–13, 34.

[14] Arcadio P. Sincero Sr., Gregogia A. Sincero (2003) Physical-chemical treatment of water and wastewater

APPENDIX I-A TABLE OF OPTIMUM PH

Alum (300000mg/L)+$FeCl_3$(300000mg/L)

Jar No.	Dosage (mg/L)	Vol of Coagulant (mL)		Expected pH	Initial pH	Final pH	TSS	Color	Turbidity	COD
		Alum	FeCl3							
1	1000	1.65	1.65	2	8.61	1.93	46	2940	146.4	523
2	1000	1.65	1.65	4	8.59	2.79	26	1050	113.4	427
3	1000	1.65	1.65	6	8.63	5.43	18	146	3.51	203
4	1000	1.65	1.65	8	8.62	6.68	40	1730	45	567
5	1000	1.65	1.65	10	8.62	8.97	44	290	67.4	574
6	1000	1.65	1.65	12	8.61	10.85	23	1020	13.7	465

Alum (300000mg/L)+$FeSO_4$(100000mg/L)

Jar No.	Dosage (mg/L)	Vol of Coagulant (mL)		Expected pH	Initial pH	Final pH	TSS	Color	Turbidity	COD
		Alum	FeSO4							
1	1000	1.65	5	2	8.44	1.89	27	1360	14.1	488.66
2	1000	1.65	5	4	8.52	3.25	55	1880	354	463
3	1000	1.65	5	6	8.52	5.77	21	1720	162	380
4	1000	1.65	5	8	8.52	7.19	24	4180	135	616.5
5	1000	1.65	5	10	8.34	9.51	29	2630	42.6	611.5
6	1000	1.65	5	12	8.54	11.12	26	800	4.82	422

$FeCl_3$(300000mg/L)+$FeSO_4$(100000mg/L)										
Jar No.	Dosage (mg/L)	Vol of Coagulant (mL)		Expected pH	Initial pH	Final pH	TSS	Color	Turbidity	COD
		Alum	FeSO4							
1	1000	1.65	5	2	8.53	1.93	30	3850	60.5	470
2	1000	1.65	3.33	4	8.55	2.83	34	1920	47.4	304
3	1000	1.65	3.33	6	8.56	5.51	21	1130	284	260.5
4	1000	1.65	3.33	8	8.61	6.84	37	2220	60.1	594.5
5	1000	1.65	3.33	10	8.57	9.21	32	2120	25.2	565
6	1000	1.65	3.33	12	8.57	10.85	47	470	10.2	425.33

APPENDIX I-B RAW SAMPLE

a) Raw sample for Alum + Ferric Chloride

Raw Sample

				TSS		
pH	COD	turbidity	Colour	before	after	final
8.82	878	90.7	5220	1.3337	1.3368	62
8.86	870	94.1	4990	1.4394	1.4428	68
8.86	880	92.1	4910	1.3264	1.329	52
8.86	877	92.3	5040			60.7

b) Raw sample for Alum + Ferrous Sulphate

Raw Sample

				TSS		
pH	COD	turbidity	Colour	before	after	final
8.72	828	160	5660	1.3465	1.3494	58
8.77	837	124	5440	1.3471	1.3511	80
8.77	873	122	5400	1.3295	1.3335	80
8.77	880	123	5500			80

c) Raw sample for Ferric Chloride + Ferrous Sulphate

Raw Sample

				TSS		
pH	COD	turbidity	Colour	before	after	final
8.64	881	143	5300	1.3431	1.3469	76
8.74	787	137	5160	1.3484	1.3516	64
8.74	880	139	5100	1.3236	1.3278	84
8.74	880	123	5186.7			74.7

APPENDIX I-C TABLE OF THE DOSAGE FOR ALUM + FERRIC CHLORIDE

Dosage	COD(mg/L)		Colour(PtCo)		Turbidity (NTU)		before	after	TSS (mg/L)	
	788		4190		66.4		1.34	1.3451	102	
200	855	821.5	4070	4130.0	67.5	66.7	1.2969	1.3017	96	99.0
	563		4130		66.3		1.341	1.3456	13	
	519		2890		96.5		1.3386	1.3435	98	
400	528	523.5	2840	2853.3	97.5	96.6	1.3236	1.3278	84	86.0
	380		2830		95.7		1.3382	1.342	76	
	365		790		25.7		1.3367	1.3406	78	
600	317	389	1010	900.0	25.2	25.7	1.3256	1.3292	72	75.0
	413		900		26.3		1.4266	1.4294	56	
	282		220		5.48		1.3268	1.3297	58	
800	236	239	260	233.3	5.05	5.2	1.4222	1.4247	50	56.0
	242		220		5.17		1.2794	1.2824	60	
	172		230		3.6		1.3402	1.3432	60	
1000	176	174	210	213.3	3.65	3.8	1.3444	1.3469	50	52.6
	174		200		4		1.3471	1.3495	48	
	175		110		4.09		1.3406	1.3428	44	
1200	176	174	110	116.7	4.28	4.2	1.3256	1.3278	44	40.0
	171		130		4.12		1.3275	1.3291	32	
	175		140		3.97		1.2828	1.2858	60	
1400	153	164	170	146.7	3.62	3.8	1.3115	1.3137	44	50.0
	128		130		3.75		1.2916	1.2939	46	
	160		790		10.1		1.3325	1.3366	82	
1600	199	179.5	790	780.0	9.78	10.2	1.3231	1.3271	80	82.0
	229		760		10.6		1.3803	1.3845	84	
	167		560		18.4		1.3117	1.3159	84	
1800	200	165.5	540	543.3	17.9	18.1	1.3353	1.3394	82	83.0
	164		530		18		1.3278	1.3308	60	

2000	183		990		57.6		1.3487	1.352	66	
	174	177	970	976.7	56.2	56.3	1.3416	1.3445	58	61.3
	174		970		55		1.3337	1.3367	60	
2200	188		1770		120		1.3503	1.3529	52	
	199	190.7	1920	1833.3	113	112.7	1.3365	1.3397	64	61.3
	185		1810		105		1.3968	1.4002	68	
2400	185		2810		174		1.4688	1.4714	52	
	317	192.5	2670	2746.7	174	171.3	1.3365	1.339	50	48.7
	200		2760		166		1.3308	1.333	44	

jar	sample volume(mL)	Dosage (mg/L)	Volume of Coagulant(mL)		Adjustment pH(expected)	pH		COD(mg/L)	Turbidity	Colour	TSS (mg/L)
			alum	FeCl3		Initial	Final				
1	500	200	0.165	0.165	6	8.61	6.4	821.5	66.7	4130	99
2	500	400	0.33	0.33	6	8.61	5.92	523.5	96.6	2853.3	86
3	500	600	0.5	0.5	6	8.61	5.86	389	25.7	900	75
4	500	800	0.67	0.67	6	8.61	5.64	239	5.2	233.3	56
5	500	1000	0.83	0.83	6	8.61	4.8	174	3.8	213.3	52.6
6	500	1200	1	1	6	8.61	4.35	174	4.2	116.7	40
7	500	1400	1.16	1.16	6	8.61	4.05	164	3.8	146.7	50
8	500	1600	1.33	1.33	6	8.61	3.81	179.5	10.2	780	82
9	500	1800	1.5	1.5	6	8.61	3.21	165.5	18.1	543.3	83
10	500	2000	1.67	1.67	6	8.61	3.13	177	56.3	976.7	61.3
11	500	2200	1.83	1.83	6	8.61	2.97	190.7	112.7	1833.3	61.3
12	500	2400	2	2	6	8.61	2.84	192.5	171.3	2746.7	48.7

APPENDIX I-D TABLE OF THE DOSAGE FOR ALUM + FERROUS SULPHATE

Dosage	COD(mg/L)		Colour(PtCo)		Turbidity (NTU)		before	after	TSS (mg/L)	
	608		3510		46.5		1.3496	1.3517	42	
200	928	724.5	3170	3343.3	48.1	47.4	1.3436	1.3461	50	46.0
	580		3350		47.7		1.419	1.4203	13	
	565		3700		78.3		1.4663	1.4679	32	
400	496	672.5	3670	3706.7	80.3	79.5	1.3939	1.3951	24	28.0
	487		3750		80		1.2918	1.2924	12	
	459		3850		114		1.3386	1.3391	10	
600	487	629.7	3800	3826.7	119	117.3	1.3429	1.3449	40	39.0
	436		3830		119		1.3213	1.3232	38	
	435		3190		142		1.336	1.338	40	
800	410	541	3150	3160.0	145	146.0	1.3297	1.3321	48	44.0
	386		3140		151		1.3353	1.3375	44	
	313		2030		106		1.3365	1.3378	26	
1000	303	440	1970	1996.7	110	108.7	1.377	1.3789	38	40.0
	311		1990		110		1.3187	1.3208	42	
	208		1660		89.1		1.3354	1.3369	30	
1200	188	376	1420	1486.7	88.5	88.8	1.3342	1.337	56	53.0
	235		1380		88.7		1.2908	1.2933	50	
	179		860		51.6		1.3223	1.3245	44	
1400	171	337.6	740	800.0	51.1	51.3	1.3446	1.3465	38	41.0
	164		800		51.2		1.3379	1.3384	10	
	136		290		47.5		1.3459	1.3473	28	
1600	136	308.5	320	303.3	49.5	50.2	1.289	1.2902	24	25.3
	171		300		53.5		1.3369	1.3381	24	
1800	121	300.7	220	230.0	49.7	49.4	1.3221	1.324	38	36.0

	100		230		48.6		1.3395	1.3413	36	
	110		240		49.9		1.3252	1.3269	34	
	105		230		39.9		1.2813	1.2826	26	
2000	102	271	200	206.7	40.5	40.0	1.3208	1.3223	30	26.7
	169		190		39.7		1.3458	1.347	24	
	91		80		26.7		1.3151	1.3171	40	
2200	99	261	100	96.7	25.3	26.2	1.4282	1.4304	44	40.0
	80		110		26.7		1.328	1.3298	36	
	82		20		28.3		1.3323	1.3344	42	
2400	90	260.3	40	26.7	28.4	28.8	1.4354	1.438	52	46.0
	83		20		29.7		1.3338	1.336	44	

jar	sample volume(mL)	Dosage (mg/L)	Volume of Coagulant(mL)		Adjustment pH(expected)	pH		COD(mg/L)	Turbidity	Colour	TSS (mg/L)
			alum	FeSO4		Initial	Final				
1	500	200	0.165	0.5	6	8.61	6.4	724.5	47.4	3343.3	46
2	500	400	0.33	1	6	8.61	5.92	672.5	79.5	3706.7	28
3	500	600	0.5	1.5	6	8.61	5.86	629.7	117.3	3826.7	39
4	500	800	0.67	2	6	8.61	5.64	541	146	3160	44
5	500	1000	0.83	2.5	6	8.61	4.8	440	108.7	1996.7	40
6	500	1200	1	3	6	8.61	4.35	376	88.8	1486.7	53
7	500	1400	1.16	3.5	6	8.61	4.05	337.6	51.3	800	41
8	500	1600	1.33	4	6	8.61	3.81	308.5	50.2	303	25.3
9	500	1800	1.5	4.5	6	8.61	3.21	300.7	49.4	230	36
10	500	2000	1.67	5	6	8.61	3.13	271	40	206	26.7
11	500	2200	1.83	5.5	6	8.61	2.97	261	26.2	96.7	40
12	500	2400	2	6	6	8.61	2.84	260.3	28.8	26.7	46

APPENDIX I-E TABLE OF THE DOSAGE FOR FERRIC CHLORIDE + FERROUS SULPHATE

Dosage	COD(mg/L)		Colour(PtCo)		Turbidity (NTU)		before	after	TSS (mg/L)	
200	775	787	5150	5053.3	60	63.0	1.3445	1.3458	26	17.0
	719		5020		64		1.3321	1.3327	12	
	868		4990		65		1.4113	1.4117	13	
400	669	671	4640	4633.3	125	120.0	1.4628	1.4639	22	12.6
	673		4620		120		1.3916	1.392	8	
	776		4640		115		1.2793	1.2797	8	
600	613	580.5	4510	4493.3	157	156.0	1.3288	1.3293	10	9.0
	727		4490		154		1.3336	1.334	8	
	548		4480		157		1.3159	1.3167	16	
800	488	428.5	3210	3210.0	140	136.0	1.3325	1.333	10	11.3
	441		3210		135		1.3208	1.321	4	
	416		3210		133		1.3356	1.3366	20	
1000	365	377	1550	1523.3	40	41.7	1.3311	1.3315	8	12.6
	319		1490		44		1.3741	1.3746	10	
	389		1530		41		1.3095	1.3105	20	
1200	493	223.5	640	680.0	10	11.0	1.3313	1.3318	10	5.3
	231		680		12		1.3293	1.3294	2	
	216		720		11		1.2771	1.2773	4	
1400	229	165.5	140	126.7	5	4.3	1.3223	1.3227	8	7.0
	172		110		4		1.3446	1.345	8	
	159		130		4		1.3379	1.3382	6	
1600	165	173.5	330	286.7	7	5.7	1.3459	1.3466	14	11.3
	182		270		4		1.289	1.2896	12	
	836		260		6		1.3369	1.3373	8	
1800	199	197	1150	1153.3	13	13.0	1.3221	1.3227	12	14.0

	198		1150		14		1.3395	1.3403	16	
	194		1160		12		1.3252	1.3259	14	
	546		2370		32		1.2813	1.2818	10	
2000	354	281	2380	2370.0	28	30.3	1.3208	1.3215	14	13.3
	208		2360		31		1.3458	1.3466	16	
	321		3700		72		1.3151	1.3157	12	
2200	673	290	3640	3656.7	70	70.3	1.4282	1.429	16	14.0
	259		3630		69		1.328	1.3287	14	
	267		5010		112		1.3323	1.3333	20	
2400	245	256	4970	5003.3	109	109.0	1.4354	1.4365	22	20.0
	352		5030		106		1.3338	1.3347	18	

jar	sample volume(mL)	Dosage (mg/L)	Volume of Coagulant(mL)		Adjustment pH(expected)	pH		COD(mg/L)	Turbidity	Colour	TSS(mg/L)
			FeCl3	FeSO4		Initial	Final				
1	500	200	0.165	0.5	6	8.58	6.63	787	63	5053.3	17
2	500	400	0.33	1	6	8.58	6.48	671	120	4633.3	12.6
3	500	600	0.5	1.5	6	8.58	6.31	580.5	156	4493.3	9
4	500	800	0.67	2	6	8.58	6.1	428.5	136	3210	11.3
5	500	1000	0.83	2.5	6	8.58	5.92	377	41.7	1523.3	12.6
6	500	1200	1	3	6	8.58	5.65	223.5	11	680	5.3
7	500	1400	1.16	3.5	6	8.58	5.39	165.5	4.3	126.7	7
8	500	1600	1.33	4	6	8.58	5.8	173.5	5.7	286.7	11.3
9	500	1800	1.5	4.5	6	8.58	3.18	197	13	1153.3	14
10	500	2000	1.67	5	6	8.58	2.99	281	30.3	2370	13.3
11	500	2200	1.83	5.5	6	8.58	2.94	290	70.3	3656.7	14
12	500	2400	2	6	6	8.58	2.76	256	109	5003.3	20

APPENDIX II-A CALCULATION ON DOSAGE FOR ALUM AND FERRIC CHLORIDE

$$1\% = \frac{1\text{g}}{100\text{g}} \text{x} \frac{10^3\text{mL}}{1\text{L}} \text{x} \frac{10^3\text{mg}}{1\text{g}} \text{x} \frac{1\text{g}}{1\text{mL}} = 10000\text{mg/L}$$

$$30\% = 30x\frac{10000mg}{L} = 300000mg / L = 300\text{g/L}$$

Sample = 250mL

For Alum or $FeCl_3$ = 0.165ml

0.165mL x 300g/L = 49.5 mg

$$\text{Dosage} = \frac{49.5mg}{250mL}x\frac{1000mL}{1L} = 198 \approx 200mg / L$$

For Alum or $FeCl_3$ = 0.33ml

0.33mL x 300g/L = 99 mg

$$\text{Dosage} = \frac{99mg}{250mL}x\frac{1000mL}{1L} = 396 \approx 400mg / L$$

For Alum or $FeCl_3$ = 0.5ml

0.5mL x 300g/L = 150 mg

$$\text{Dosage} = \frac{150mg}{250mL}x\frac{1000mL}{1L} = 600mg / L$$

For Alum or $FeCl_3$ = 0.67ml

0.67mL x 300g/L = 201 mg

$$\text{Dosage} = \frac{201mg}{250mL} x \frac{1000mL}{1L} = 804 \approx 800mg/L$$

For Alum or $FeCl_3$ = 0.83ml

0.83mL x 300g/L = 99 mg

$$\text{Dosage} = \frac{249mg}{250mL} x \frac{1000mL}{1L} = 996 \approx 1000mg/L$$

For Alum or $FeCl_3$ = 1ml

1mL x 300g/L = 300 mg

$$\text{Dosage} = \frac{300mg}{250mL} x \frac{1000mL}{1L} = 1200mg/L$$

For Alum or $FeCl_3$ = 1.16ml

1.16mL x 300g/L = 348 mg

$$\text{Dosage} = \frac{348mg}{250mL} x \frac{1000mL}{1L} = 1392 \approx 1400mg/L$$

For Alum or $FeCl_3$ = 1.33ml

1.33mL x 300g/L = 399 mg

$$\text{Dosage} = \frac{399mg}{250mL} x \frac{1000mL}{1L} = 1596 \approx 1600mg/L$$

For Alum or $FeCl_3$ = 1.5ml

1.5mL x 300g/L = 450 mg

$$\text{Dosage} = \frac{450mg}{250mL} x \frac{1000mL}{1L} = 1800mg/L$$

For Alum or $FeCl_3$ = 1.67ml

1.67mL x 300g/L = 501 mg

$$\text{Dosage} = \frac{501mg}{250mL} x \frac{1000mL}{1L} = 2004 \approx 2000mg/L$$

For Alum or $FeCl_3$ = 1.83ml

1.83mL x 300g/L = 549 mg

$$\text{Dosage} = \frac{549mg}{250mL} x \frac{1000mL}{1L} = 2196 \approx 2200mg/L$$

For Alum or $FeCl_3$ = 2 ml

2mL x 300g/L = 600 mg

$$\text{Dosage} = \frac{600mg}{250mL} x \frac{1000mL}{1L} = 2400mg/L$$

APPENDIX II-B CALCULATION ON DOSAGE FOR FERROUS SULPHATE

$$1\% = \frac{1\text{g}}{100\text{g}} \text{x} \frac{10^3\text{mL}}{1\text{L}} \text{x} \frac{10^3\text{mg}}{1\text{g}} \text{x} \frac{1\text{g}}{1\text{mL}} = 10000\text{mg/L}$$

$$10\% = 10x\frac{10000mg}{L} = 100000mg/L = 100\text{g/L}$$

Sample = 250mL

For $FeSO_4$ = 0.5ml

0.5mL x 100g/L = 50 mg

$$\text{Dosage} = \frac{50mg}{250mL}x\frac{1000mL}{1L} = 200mg/L$$

For $FeSO_4$ = 1mL

1mL x 100g/L = 100 mg

$$\text{Dosage} = \frac{100mg}{250mL}x\frac{1000mL}{1L} = 400mg/L$$

For $FeSO_4$ = 1.5mL

1.5mL x 100g/L = 150 mg

$$\text{Dosage} = \frac{150mg}{250mL}x\frac{1000mL}{1L} = 600mg/L$$

For $FeSO_4$ = 2mL

2mL x 100g/L = 200 mg

$$\text{Dosage} = \frac{200mg}{250mL} x \frac{1000mL}{1L} = 800mg/L$$

For $FeSO_4$ = 2.5mL

2.5mL x 100g/L = 250 mg

$$\text{Dosage} = \frac{250mg}{250mL} x \frac{1000mL}{1L} = 800mg/L$$

For $FeSO_4$ = 3mL

3mL x 100g/L = 300 mg

$$\text{Dosage} = \frac{300mg}{250mL} x \frac{1000mL}{1L} = 1200mg/L$$

For $FeSO_4$ = 3.5mL

3.5mL x 100g/L = 350 mg

$$\text{Dosage} = \frac{350mg}{250mL} x \frac{1000mL}{1L} = 1400mg/L$$

For $FeSO_4$ = 4mL

4mL x 100g/L = 400 mg

$$\text{Dosage} = \frac{400mg}{250mL} x \frac{1000mL}{1L} = 1600mg/L$$

'or $FeSO_4$ = 4.5mL

4.5mL x 100g/L = 450 mg

$$\text{Dosage} = \frac{450mg}{250mL} x \frac{1000mL}{1L} = 1800mg/L$$

For $FeSO_4$ = 5mL

5mL x100g/L = 500 mg

$$\text{Dosage} = \frac{500mg}{250mL} x \frac{1000mL}{1L} = 2000mg/L$$

For $FeSO_4$ = 5.5mL

5.5mL x 100g/L = 550 mg

$$\text{Dosage} = \frac{550mg}{250mL} x \frac{1000mL}{1L} = 2200mg/L$$

For $FeSO_4$ = 6mL

6mL x 100g/L = 600 mg

$$\text{Dosage} = \frac{600mg}{250mL} x \frac{1000mL}{1L} = 2400mg/L$$

APPENDIX III EFFLUENT PARAMETER LIMIT STANDARD

Environmental Quality (Sewage and Industrial Effluents) Regulations, 1979. Maximum Effluent Parameter Limits Standards A and B.

Parameters		(Units)	Standard	
			A (1)	B (2)
1	Temperature	°C	40	40
2	pH	-	6.0 - 9.0	5.5 - 9.0
3	BOD5 @ 20oC	mg/l	20	50
4	COD	mg/l	50	100
5	Suspended Solids	mg/l	50	100
6	Mercury	mg/l	0.005	0.05
7	Cadmium	mg/l	0.01	0.02
8	Chromium, Hexalent	mg/l	0.05	0.05
9	Arsenic	mg/l	0.05	0.10
10	Cyanide	mg/l	0.05	0.10
11	Lead	mg/l	0.10	0.5
12	Chromium, Trivalent	mg/l	0.20	1.0
13	Copper	mg/l	0.20	1.0
14	Manganese	mg/l	0.20	1.0
15	Nickel	mg/l	0.20	1.0
16	Tin	mg/l	0.20	1.0
17	Zinc	mg/l	1.0	1.0
18	Boron	mg/l	1.0	4.0
19	Iron (Fe)	mg/l	1.0	5.0
20	Phenol	mg/l	0.001	1.0
21	Free Chlorine	mg/l	1.0	2.0
22	Sulphide	mg/l	0.50	0.50
23	Oil and Grease	mg/l	Not detectable	10.0

1. **Standard A for discharge upstream of drinking water take-off**
2. **Standard B for inland waters**